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**PANEL ON PUBLIC POLICY**  
**ON**  
**NUCLEAR ENERGY**  
**FOR**  
**ELECTRICITY GENERATION**

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**PRELIMINARY REPORT**

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**UNIVERSITY OF MARYLAND**  
**CENTER FOR ENVIRONMENTAL AND ESTUARINE STUDIES**

**December, 1975**



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January 5, 1975

The Honorable Marvin Mandel  
Governor of Maryland


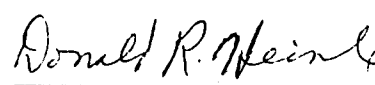
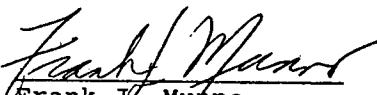
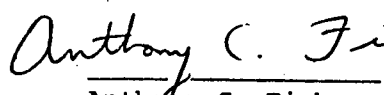

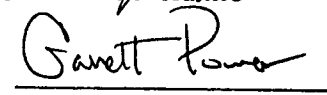

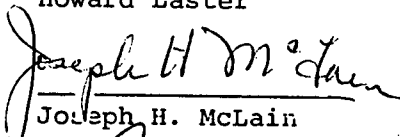

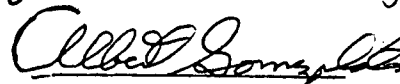
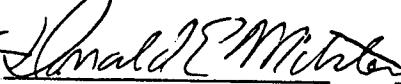
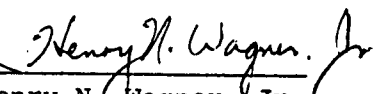
Dear Governor Mandel:

The undersigned Panel, appointed at your direction by Mr. L. E. Zeni, Administrator, Energy and Coastal Zone Administration, herewith submits its Preliminary Report. Our Final Report, which will include data and documentation, will be submitted by March 1, 1976, following public meetings to be held at various places throughout the State.

In the conduct of this study, the Panel has enjoyed the wholehearted cooperation of the public utilities, members of government, research organizations, and interested citizens. We are grateful for this assistance and for the participation of a notable roster of speakers, and take this means of expressing our thanks.

It is fitting to report that the conclusions and recommendations which follow have the support of all members of the Panel.

Sincerely yours,

 Doris Entwisle	 Donald R. Heinle	 Frank J. Munno
 Anthony C. Fisher	 Howard Laster	 Garrett Power
 John C. Geyer	 Joseph H. McLain	 Robert H. Roy
 Albert Gomezplata	 Donald E. Milsten	 Henry N. Wagner, Jr.

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Robert H. Roy, Chairman  
John C. Geyer, Vice-Chairman  
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Anthony C. Fisher  
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# ERRATA

- Page 7, Lines 6 and 7: For augumented read augmented
- Page 10, Item 21: For moritoria read moratoria
- Page 24, Line 7: For with read within
- Page 44, Line 19: For vacinity read vicinity
- Page 53, Line 13: For hydrogen, cyanide read hydrogen cyanide
- Page 56, Line 1: Read as end of last line on preceding page.

PANEL ON PUBLIC POLICY ON NUCLEAR ENERGY FOR  
ELECTRICITY GENERATION

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Introduction

Power plants, especially new ones, have become subjects of controversy within recent years, and nuclear power plants in particular have become targets of opposition by concerned citizens. Electricity is acknowledged to be an essential form of energy but there are some who believe that the provision of more energy can be avoided by conservation, and there are others who concede the necessity for energy growth but would forbid the use of atomic fission to provide the additional electricity needed. The issues have become clouded by combinations of uncertainty, mistrust, time, cost and above all fear.

The Panel which has prepared this Report was appointed at the direction of Governor Mandel. His charge, which was given to Mr. L. E. Zeni, Administrator, Energy and Coastal Zone Administration, was communicated by letter of June 13, 1975, parts of which read as follows:

"I am directing the Power Plant Siting Program to enter into an agreement with the University of Maryland Center for Environmental and Estuarine Studies for the conduct of a study directed toward the formulation of public policy on the future use of nuclear energy for the generation of

electricity in Maryland. The study is to be carried out by an academic panel of various disciplines appointed from the universities and colleges of the State.

"The panel will consider the safety, welfare, and continuing prosperity of the citizens, organizations, and institutions of the State. It will be neither an advocate nor an opponent, but rather will make every effort to receive and report factual information about such matters as:

"The prospective demand for electricity during coming decades and the energy sources from which these demands may be met;

"The comparative characteristics of nuclear and fossil fuel power plants;

"Problems incidental to power plant location, construction and operation, including such matters as aesthetic, environmental, economic, and social impacts, and health, safety, and security issues;

"Problems arising from the creation, transportation, reprocessing, and disposition of fission products; and

"Prospective new technologies and their potential benefit and costs.

"In carrying out its charge, the panel will hold public meetings and hearings to assure adequate input from knowledgeable professionals and the public."

These missions have been carried out by the Panel identified in Appendix A (p. 85 ) and by the meetings detailed in Appendix B (p. 87). In arranging meetings the Panel made particular efforts to hear from opponents as well as advocates of nuclear power but we were less successful in having our invitations accepted by those in opposition. We did, however, include the extensive documentation of neutrality, opposition, and advocacy in our wide-ranging review.

Before examining each of the specific topics which follow and the policy recommendations which attend them, we disclaim any special wisdom or prescience. We do claim that we have tried to be objective and unbiased and that we desire to preserve the integrity and safety of the environment in which we and our children and grandchildren will live.

Additionally and comparably pertinent is the unanimity with which we have reached the conclusions stated and the recommendations made. During the writing and editing of this Report there have been differences of opinion which have led to changes in substance and emphasis but ultimate agreement permits us to state our conclusions and recommendations with conviction.

This Preliminary Report begins with a Summary of Conclusions and Recommendations, followed by chapters which review Policy Issues and Technologies for the Generation of Electricity. All of the Report has been prepared in a manner intended to be

comprehensible to the general public. The Final Report, to be submitted by March 1, 1976, will contain additional details and documentation.

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SUMMARY OF

CONCLUSIONS AND RECOMMENDATIONS



## CONCLUSIONS

1. Conservation of energy - all energy, not just electricity - will be essential during coming decades.

2. Despite conservation, the demand for electricity will continue to increase. The supply of electricity must also increase.

3. Demand for electricity will be augmented by economic growth. Demand also will be augmented by substitution: shifts away from oil and gas, due to economic and political constraints, depletion, and preemption of these fuels for other purposes will add to the demand for electricity.

4. Technologies such as solar, wind, and fusion are promising for the future but are not yet practical or economical for the large scale generation of electricity in Maryland.

5. To meet increases in the demand and supply of electricity during the next one or two decades there are only two feasible sources of energy: coal and fission of the atomic nucleus.

6. Reserves of coal are adequate to meet the needs of electricity generation for many decades. However, sufficiently rapid expansion in the mining, transportation, and treatment of coal will be difficult and costly.

7. Reserves of nuclear fuel are sufficient to meet the needs of some hundreds of prospective additional nuclear power reactors. Ultimately, the supply of uranium will become a limiting factor unless breeder reactors become operational.

8. The capital cost of nuclear power plants is higher than the capital cost of comparable coal-fired facilities.

9. Capital costs for both coal and nuclear power plants are increased by long lead times, inflation, high interest rates, safety and environmental costs, and the inherent capital intensity of the utility industry. Problems of capital scarcity derive from these forces.

10. Operating and fuel costs are less for nuclear power plants than for comparable coal-fired plants.

11. In general, the overall cost of electricity from nuclear plants is less than from comparable coal plants. There are exceptions to this general conclusion: relative costs of the two technologies change with time and also vary from facility to facility.

12. The environmental disadvantages of coal include impacts of air pollution, public and occupational morbidity and mortality, and impacts of mining, transportation, and disposal of very large tonnages of coal, ash, and sludge.

13. The environmental disadvantages of nuclear power plants include the dissipation of additional increments of waste heat into bodies of water or the atmosphere adjacent to each power plant. Releases of radioactive materials at nuclear power plant sites which result from ordinary plant operation do not present a significant hazard to human health.

14. The environmental disadvantages of the nuclear fuel cycle, which comprehends mining, enrichment, fabrication, and reprocessing, includes releases of radioactive materials, some

of them long-lived and highly toxic, to the environment. Appropriate limits for such releases are being set by the Environmental Protection Agency. Article 43, Section 689B of the Annotated Code of Maryland now forbids the establishing of permanent storage or reprocessing facilities for nuclear materials within the State.

15. On balance, the nuclear generation of electricity is environmentally less detrimental than generation from coal.

16. Both nuclear and coal technologies are acceptably safe. Nuclear power does have a relative disadvantage in that accidents releasing substantial quantities of radioactivity to the environment are possible, although unlikely, at a nuclear power plant. The consequences of such an accident would typically be much less than is popularly believed and, when both possibility and expected consequences are considered, the risk to society is judged to be less than from many other commonly accepted technologies.

17. A commitment to operate several hundred power stations in the United States would make the occurrence of at least one such accident a realistic possibility within the next 50 years. This conclusion points up the vigilance and caution that government and the public must exercise over nuclear safety.

18. Nuclear weapons programs, both here and in many countries elsewhere in the world, have created large quantities of radioactive wastes, some of which are dangerous and toxic.

Also present is plutonium, a material which could be formed into a bomb or dispersed as a potential health hazard. Safeguarding this material from theft and possible use by saboteurs or terrorists is essential.

19. Plutonium is already so widespread throughout the world that unilateral action by the United States cannot provide the necessary safeguards. International cooperation will be essential.

20. A large scale national commitment to nuclear power, accompanied by recycling of plutonium and/or the development of breeder reactors, will increase the amount of plutonium in use, transit, and storage. This will require the establishment and maintenance at all times of security of power plants, transportation modes, and reprocessing plants. Safeguarding is a serious problem currently being studied by the Nuclear Regulatory Commission.

21. Because of the pervasive presence of plutonium, problems of safeguarding can not be solved by strategies of moratoria or rollbacks applied to commercial nuclear power.

22. The operation of nuclear power plants and production of nuclear weapons both require storage or disposal of long-lived radioactive materials. At present military wastes are stored in liquid form in tanks above ground. Wastes from nuclear power plants will be stored in solidified form, an appreciably safer method. Both of these arrangements are considered temporary.

23. It appears that commercial nuclear wastes will ultimately be stored as ceramic materials within deep salt formations in the Southwest. The Panel believes that this will prove to be an acceptable solution, one that will not unduly jeopardize future generations.

24. Increases in the demand for electricity in Maryland will require additional power plants. Some of these plants will utilize fission of the nucleus and some will utilize coal. In planning a new power plant, each utility, as in the past, will propose its own preference between these energy alternatives. Each such proposal will then be evaluated by appropriate agencies of the Federal government and, uniquely in Maryland, by the Power Plant Siting Program. Effective evaluation can protect the welfare of the State and its citizens.

## RECOMMENDATIONS

1. We recommend that the State keep its energy options open. Nuclear energy is recommended as a possible choice; so also is coal; so also are other possible energy sources.

2A. Toward the conservation of electricity we recommend economic and statutory inducements to diminish excessive use.

B. To the same end we recommend the establishment and maintenance of programs which will encourage more effective voluntary conservation.

C. Inducements are recommended to shift consumption of electricity from daily and seasonal load peaks to off-peak periods, in order to minimize the need for construction of costly new generating facilities.

3. We recommend that the blanket prohibition or re-processing and permanent storage of nuclear materials in Maryland, promulgated by Article 43, Section 689B of the Annotated Code of Maryland, be modified. Problems of re-processing and storage are of national and international scope, not amenable to evaluation and regulation by the several states.

## POLICY ISSUES



## FORECASTS OF DEMAND

For reasons which will be given presently, policies conducive to conservation in the generation and consumption of energy - all energy not just electricity - are desirable and necessary. By the end of the century, or not long thereafter, growth rates to which we have become accustomed and upon which we have come to depend may decline significantly.

This decline may occur regardless of whether Maryland's policy encourages or discourages the change. Pressures in our society already are slowing demand growth and these may require legislative intervention to minimize economic and social dislocations. We believe conservation to be essential in any long-term energy strategy.

But for the present and immediate future, until 1985 or 1990, cessation of growth in the generation and use of electricity does not appear to be either possible or desirable. Conservation is desirable but there will be growth despite husbandry. National forecasts of increases in the demand for electricity range from less than three to more than seven per cent per year. Forecasts in Maryland, required by law of the utilities which serve the State, are somewhat higher than the national minimum; Maryland continues to be an area of higher than average growth in both public and private sectors of the economy - and growth equates to increased use of energy.

One cannot say with certainty but it is possible that these growth rates in demand may be exceeded due to sub-

stitution of electricity for other forms of energy. Increasingly, electricity will become a substitute for oil and gas in transportation and in space heating. If mass transit systems are developed and used more extensively, if small electric cars become economically and technologically feasible, and if solar energy is developed in conjunction with electrically powered heat pumps for space heating, demand forecasts will be higher than have been anticipated. During the next 15 years or more demand for electric energy will increase.

Should supply increase to meet this demand? Can we make do with what we have by combinations of frugality, efficiency, peak smoothing, and, when necessary, rationing or interrupting service? The Panel believes that our society cannot long tolerate a cessation or diminution in the supply of electricity. We believe that conservation alone will be inadequate to prevent major social and economic disruptions unless reasonable increases in supply are provided.

Not so long ago a large power plant could be conceived, designed, built, and operated within five years. Today, for reasons which are discussed in a later section, lead times have increased to six to eight years for a fossil fuel plant and to about ten years for a nuclear plant. If supply must be increased, as we have just concluded, additional power plants will be needed, and the need for each additional or replacement plant must be predicted and the enterprise launched years in advance.

Many citizens do not want a power plant nearby, especially when a rural or marine environment appears to be threatened as a consequence. Such concerns have often led to adoption of desirable design alternatives. Sometimes, however, intervention has caused delays. Because of long lead times, delays in making decisions about new power plants can lead to power shortages and cost increases. Objections are necessary, even desirable, but expedition in decision making and execution will be essential, if we are to avoid a power shortage within the next decade.

#### CONSERVATION

Americans have become accustomed to an on-call supply of abundant electricity at prices which have remained low for decades; growth and progress are American expectations, and except in the face of evident threat, citizens and their elected representatives will not willingly accept or impose the restraints of austerity.

Despite these societal and political realities, and despite the fact that a power shortage is not now foreseen by most citizens, the Panel recommends adoption of policies designed to reduce growth in the use of electricity.

The means used to achieve conservation will require economic and political artistry and careful timing. If applied to quickly or too drastically, economic rewards or

sanctions would cause dislocations more costly than the benefits derived.

More specifically, we recommend policies which will:

1. Restrain excess use,
2. Promote voluntary conservation.

1. Restraining Excessive Use

"Excessive" use of energy is as difficult to define as it will be to control, for that which may be deemed excessive to some will be regarded as proper and necessary by others. It would seem, therefore, that restraints upon excessive use might well combine prohibitions at the extremes of consumption and price differentials within the area of consumer judgment.

Analogies to this recommendation already exist. Setting and enforcing a speed limit of 55 miles per hour for automobiles and trucks is a mandate designed to conserve gasoline and diesel fuel, and the many discussions of price and tax increases in automotive fuel are examples of influencing use by market forces.

Toward the conservation of electricity we recommend policies of the same kinds. As an example, temperature limits for space heating and cooling might be specified in a manner analogous to the 55-mile speed limit. Such limits might be enforced by adoption and extended use of tamperproof thermostats, perhaps mandated for all new installations.

Analogously, tax advantages might be offered to citizens

and organizations willing to insulate and weatherstrip dwellings and places of business. Revisions in the Building Code might also be made for purposes of energy conservation.

The specific policies mentioned here are intended only as illustrations. Our recommendations are for policy makers to conceive and employ all suitable contributions of law and market forces to encourage conservation in the use of electricity.

## 2. Promoting Voluntary and More Effective Conservation

Preceding recommendations have proposed technological, legal, and economic measures for the conservation of energy. We propose that these measures be augmented by policies which may persuade citizens voluntarily to practice greater frugality. Americans, notoriously profligate in their use of resources, could add a very large increment to our energy reserves if prodigality gave way to more temperate use.

Substantial voluntary conservation effort could be secured by education of consumers on topics related to power consumption. Homemakers, for example, do not know which of their many appliances are major users of electricity. Informing them that hot water heaters and clothes dryers are high-demand appliances could well lead to increased use of cold water detergents and sun drying. Encouragement to turn off radios and televisions and household lights when they are not in use or needed would effect savings of lesser magnitude but their importance should not be neglected.

In the same way stores, restaurants, and industrial establishments might be persuaded to reset air conditioning controls to higher levels than have been customary in the past.

Studies of patterns of consumer use could be of great value in contributing to voluntary conservation.

We are persuaded that efforts to publicize the need for conserving electricity and leadership in doing so by government and by the utilities will win favorable response. We also believe, however, that effectiveness of campaigns hinges on the provision of specific and realistic direction. Consumers do not presently know how best to conserve power. Many well intentioned people are just not informed about where and how the largest savings can be made. In the words of one of our speakers: Conservation is the largest single source of new energy quickly available to us.

#### Peak Smoothing

Another policy, directed more to protection of the environment and the conservation of capital than to direct conservation of energy, is peak smoothing. All electric utilities must have sufficient generating capacity to meet demands occasioned by daily and seasonal peak loads. The distance between the tallest of these peaks and the level of the more constant base load is a rough economic measure of the additional capital and operating costs required to

meet sporadic demands. Expressed differently, the extent to which peak loads can be "clipped" can be a contribution to the avoidance of power shortages, and can reduce the need for new power plant construction and use of less efficient generating equipment.

We recommend, therefore, that action be taken in as many ways as possible and as quickly as possible to diminish on-peak and encourage off-peak use of electricity: for example, by extension of peak-avoiding timing devices to appliances and by rate differentials which, in effect, reward off-peak users and penalize peak demands.

#### TECHNOLOGICAL MEANS

During all of this century most electricity has been generated by engines driven by steam vaporized from water by the combustion of coal, oil, or gas. Most citizens do not understand the complexities of this vast thermal-electric system but they do enjoy a take-it-for-granted familiarity with it.

Fossil fuel combustion is still the dominant method but now there is a challenger technology: that of vaporizing water into steam by heat derived from fission of the atomic nucleus. This technology is garbed in mystery and tainted by the imagery of Hiroshima. Everyone knows what it means to burn coal; few know what it means to split the atom. The

connotations of combustion are benign; those of fission foreboding.

These misgivings have taken expression in opposition to the use of nuclear energy and in hopes for substitute sources of energy that will be cheap, clean, and abundant. Some of these surrogates do hold promise for providing increments to meet our energy needs but realization is bounded by economic reality and lies years ahead. In more than a few cases citizens and their representatives in government have been beguiled by false hopes nourished by the apprehensions of the 1973-1974 oil embargo.

In the following sections of this chapter we compare the advantages and disadvantages of various generating technologies, featuring coal and present day nuclear power plants. Our discussion emphasizes expository simplicity at the expense of technical detail. For those readers who are unfamiliar with present and foreseeable generating technologies, a background description is provided in the next chapter (page 55).

## RESOURCES

### Financial Resources

All of the electric utilities which serve Maryland are investor-owned and subject to regulation by the Maryland Public Service Commission. Permissible earnings are calculated

by multiplying an allowable rate of return times the value of each electric generating facility. While the intention of such rate-making is to guarantee a predetermined "fair return on investment", actual earnings have been enhanced by improvements in operating efficiencies over time and by steady growth in the sale of electricity.

These once favorable conditions have changed in ways which now confront utilities with serious financial problems. Rising costs and a slow down in demand growth have lowered the effective rate of return; lower dividends, the general economic down turn, and high interest rates have depressed industry securities and made it more difficult to raise capital required for construction of new generating stations. Hence, unless positive steps are taken there is a real possibility of a power shortage within the next decade.

This possibility leads the Panel to make two pleas. First, we ask for leadership by both government and utilities in the conservation of energy. Government leadership will not be easy because of the incompatibility between our political processes and austerity measures; utilities will likewise find it incongruous to discourage the sale of electricity. Second, we ask the rate-making agencies to take rising costs and diminishing growth rates into account. Energy is a commodity of which it may be said that we must all huddle together or we shall all freeze separately.

### Energy Resources

All of the energy which sustains us, save that which comes from the atom, is derived from the sun, as everyone knows. Most of this enormous beneficence is temporal; it falls diurnally upon the earth and seas and is reflected or radiated back to the outer space through which it came. Some of it is captured and stored in watersheds and in fossil fuels, stored for aeons and used intensively only with recent times. Exponential growth in use of fossil fuels has brought us face to face with depletion, aggravated by dependence upon others for continuity of supply. We are compelled to husband our own resources and to consider alternatives: new sources of stored energy and new ways to capture and use more of the energy which comes to us from the sun but now escapes us.

Other ways to capture and use what has been called the temporal energy received from the sun are to harness the winds, tides, waves, and temperature differentials of the oceans, and to capture and use the direct rays of the sun for space heating or for the generation of electricity.

With respect to stored energy, the availability and longevity of reserves are dependent not only upon the earth's inventories and their geographic locations but also upon the economics of recovery and refinement. Elsewhere, data on reserves are given; in this more general exposition the following conclusions may be stated:

United States reserves of natural gas and oil are insufficient for our needs.\* If we continue to use these fuels for the generation of electricity we will become increasingly dependent upon foreign sources, sources which also will be depleted within several decades unless current patterns of use are altered. We know how to generate electricity from sources other than oil but do not know how to make fertilizer, polyesters, dyes, or medicines, or to fly aircraft without the products of petroleum. Petroleum is an essential resource for which other chemical alternatives are lacking.

United States reserves of coal are ample but there are serious questions about the feasibility and desirability of expanding and converting electricity generation exclusively or predominantly to coal. Inherent in coal technology are very difficult problems of mining, transportation, treatment, and environmental damage, problems which are discussed below. Reserves of coal convenient to Maryland contain more sulfur than is desirable, while that which contains less sulfur lies in the West at distances which make transportation costly.

United States reserves of fissionable uranium are much less than our reserves of coal but, still, are sufficient to fuel many power plants.

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\*The level of U. S. reserves can be modified by factors such as price increases, new discoveries, or technological improvements. However, we see no realistic hope that such factors could allow historical growth in oil consumption to continue for any substantial period of time.

As a corollary to the availability of fissionable uranium, development of breeder reactors, which produce more fuel than they consume, would insure energy supplies for centuries to come. Should controlled fusion eventually be realized, energy supplies would, in effect, become limitless. The history of technology suggests that some day these goals may be reached but attainment is so difficult that we do not recommend anticipation of nor dependence upon these technologies during the next decade or two.

Another important resource is hydroelectric power. This resource is important in Maryland but most feasible sites already have been utilized and it is not likely that we shall be able to augment our supply of electricity by additional hydro plants.

Beyond these more familiar energy resources are some which are less conventional. Use of the direct rays of the sun and harnessing the winds, waves, tides, and temperature differences between the surface and core of the earth and surface and depths of the oceans are under development but it does not appear that these technologies can be made operationally effective except on a very limited scale until 1985-1990. At that time some of them can be expected to contribute significant increments of our needs but not enough - nor soon enough - to permit delays in new power plant planning, construction, and operation.

Given present world conditions, the only feasible alternatives for major additions to generating capacity are nuclear and coal. We believe that it will be difficult to meet Maryland's electricity needs without use of both technologies.

# ECONOMIC COMPARISONS

For the generation of electricity, the unconventional technologies just described have been declared to be uneconomical relative to the technologies of fossil fuels and nuclear fission. Since the differences are large, the margin of superiority of coal and nuclear power over energy from direct sunlight, wind, etc. is not likely to be overcome in less than a decade or two and perhaps not then. This discussion, therefore, will be confined to comparing the capital and operating costs of power generated from coal with capital and operating costs of power generated from atomic fission.

Nearly all of the oil and coal vs. nuclear comparisons that have come to our attention favor nuclear energy in the manner shown by the following table:

ECONOMIC COMPARISON OF 2-1160 MW GENERATING UNITS\*  
(MILLS/KWHR)

		<u>COAL</u>			
		<u>OIL</u>	<u>SCRUBBERS</u>	<u>TALL STACKS</u>	<u>NUCLEAR</u>
CAPITAL	1975	3.1	4.7	3.5	7.8
	1985	11.3	15.9	13.0	22.5
FUEL	1975	20.6	14.0	12.9	2.6
	1985	31.5	26.2	24.0	3.4
OPERATING AND MAINT.	1975	1.2	2.7	1.3	1.5
	1985	1.7	3.6	1.8	2.1
TOTAL	1975	24.9	21.4	17.7	11.9
	1985	44.5	45.7	38.8	28.0

\*Courtesy Philadelphia Electric Company

To make such calculations it is necessary to make various assumptions about the cost of equipment, the amount of money which will be required to design and construct a new plant, the cost of that money over the developmental time span, the trend of inflation, the cost of fuel, the cost of labor and the load factor at which the new plant may be expected to operate.

It is possible to alter such results as are shown by making assumptions which favor one or the other technology. Longer lead times for nuclear power and conjecture of a high rate of inflation, for example, would increase nuclear capital costs; assumptions of higher costs for reactor fuel and lower nuclear load factors would also favor fossil fuel technologies. Conversely, estimations for fossil fuel power can be altered in the same way.

It is also possible to alter these comparisons by assumptions about the expected reliability of nuclear power plants over time. Opponents predict poor reliability for nuclear power plants and cite the performance of three of the oldest reactors as evidence of this expectation. The Panel believes, however, that there is no firm basis for predicting which technology, nuclear or fossil fuel, will ultimately prove the more reliable. Both fossil fuel and nuclear plants are less reliable than their designers would like them to be. Improvements in reliability of either or both technologies would lead to con-

siderable savings for Maryland consumers. We endorse efforts to find safe and environmentally acceptable methods of improving plant reliability by both utilities and government.

While the calculations we have seen vary because of such judgments, the assumptions have been reasonable and the results consistent: in Maryland the cost per kilowatt hour for electricity generated from nuclear fission is and probably will continue to be less than the cost of generating equivalent amounts of electricity from the combustion of coal.

We have already said that increased utilization of both coal and uranium will be necessary during the next two decades. The cost comparison just stated bespeaks a policy favoring nuclear fission as the economically preferable technology.

This policy statement is reinforced by the history of technological progression. New technologies typically develop slowly and then after a period of time realize rapid and significant improvements, followed by a mature period during which gains are made in smaller increments. Developments in nuclear power are following such a pattern, and if this continues the economic gap between the new technology of the atom and the older technologies of fossil fuels will be more favorable to nuclear power than is the case now.

While this prediction is probably accurate, there are dimensions to technological progression in nuclear power that are different and perhaps unique. Capital intensity,

technological complexity, and entrepreneurial risk have brought about governmental support, sponsorship, and regulation, and it appears likely that government will continue to play a major role in the entire nuclear cycle.

Maryland, through the excellence of its Power Plant Siting Program, is in an exceptional position with respect to these government-utility relationships. So far, the Program has dealt primarily with power plants per se; now, however, concern is shifting to include such matters as fuel enrichment, reprocessing, and spent fuel storage. The Program's staff expertise will need to be extended to these areas as well, in order that Maryland's representatives at State and Federal levels may be best advised.

#### ENVIRONMENTAL IMPACTS

Today, few topics are more widely discussed than the environment. Some believe that the environment must be preserved as is: the wilderness, countryside, and waters must remain unspoiled; preservation or restoration of those places which already have been altered by man must be undertaken. Recognizing that man and technology inevitably encroach upon the environment, others stress conservation, and acknowledge society's dependence upon technology but insist upon minimization of its deleterious effects as well as realization of its benefits.

As we evolved our proposals, we on the Panel found ourselves to be conservationists. We concluded that it would be neither possible nor desirable to stop technological progress. To do so might cause economic and social insults far worse than damage to the environment from new technology. The problem is to assess potential damage in advance in order to progress technologically in ways that will minimize adverse environmental consequences.

All of the products and apparatus of technology, from an ordinary pin to an extraordinary space ship, impose environmental burdens. So, of course, do power plants, whether fueled by coal, oil, gas or fission, or driven by the fall of water, or by the wind, sun, tides, or waves. Most of these affect the environment in the same way: generation of electricity involves the creation of heat which ultimately finds its way into the environment. This heating effect is not yet restraining but some day may be. A basic premise is that all technology imposes environmental impacts which must be considered, anticipated, and controlled.

Among electric power alternatives, all require large installations and there are other characteristic environmental effects. Hydro power necessitates changes in the aquatic environment and initial removal of all who dwell in the valleys drowned by dams, dams which on occasion expose those who live downstream to hazard. Windmills numerous enough to

generate significant amounts of electricity would intrude upon the land or seascape, so would solar heat collectors or solar cells, so would generators dependent upon ocean temperature differences, so would tidal or wave devices. Fossil fuel and nuclear power plants also are very large installations and they also impose aesthetic burdens upon the landscape. For those power plants which we must have, it is therefore important that architecture do everything possible to make them pleasing to the eye.

Environmental effects are also associated with transmission lines, and such impacts become more severe as the line voltage is increased. Environmental effects include electromagnetic radiation, audible noise, ozone production, and electric fields. With the exception of electric fields, all of these are intensified during foul weather. Electromagnetic radiation can cause interference to nearby radios, television receivers, and other communications equipment. Noise can be annoying to nearby residents during some weather conditions such as fog. Ozone is a toxic gas, but it is common in the environment and the additional ozone generated by transmission lines is not expected to be an environmental problem at presently used voltages. Electric fields produced by the lines can cause annoying spark discharges, in some cases, to people who touch metallic objects within or adjacent to the transmission corridor. In addition, there is speculation

about the health effects of prolonged exposure to high intensity electromagnetic fields. It should be noted that the severity of all these effects depend on many factors, including the design of the transmission facilities and the proximity of residents.

Other environmental issues relate to land use and population displacement. There are also potential effects associated with construction and maintenance of the corridors, such as the possibility of environmental damage due to erosion or use of herbicides.

There have been many proposals to run transmission lines underground; this is feasible for short distances but still much too costly as the general mode of transmission. Electricity rates and capital requirements would be intolerably high if underground transmission were required.

Finally, it should be noted that the impacts of transmission lines relate only tangentially to the choice of generating technology. The impact of the lines will depend on the size and location of the plant and the proximity of the load centers. Thus, a nuclear and fossil fuel plant of equal electrical power will differ in transmission line impacts only if and as they need to be sited in differing locations. Conversely, the need to minimize transmission corridors is often an important reason for choosing one site over another.

In the aggregate, environmental impacts of transmission lines are local, temporal, and acceptably small, if suitable care is given to design and siting.

### The Steam Cycle

The generation of electricity by means of steam, vaporized either by the combustion of fossil fuel or nuclear fission and thereafter condensed, involves a number of environmental consequences.

#### Once-through Cooling

Condensers which use once-through cooling draw water from whatever the reservoir may be, and discharge it, now warmed by spent steam from the turbine, into the same reservoir from which it was obtained. Because estuarine and ocean waters are large bodies and enjoy the heat diffusing benefits of winds, waves, and tides, they become reservoirs of choice for power plants using once-through condensing. The Chesapeake Bay and the Atlantic Ocean are of particular importance as sources and sinks for this method of cooling.

Use of natural waters in this way creates several kinds of potential environmental problems:

1. Flow in cooling water intakes can trap fish and crabs which are then carried on to the screens and destroyed. This problem is reduced by placing the

inlet at a depth to which mobile creatures are less likely to swim, by making the inlet large and the velocity of entering water small, and by designing inlet screens from which fish can escape or be removed without harm. These measures have ameliorated the problem. Further research and experience should reduce entrapment to an occasional problem but minor losses to entrapment will continue.

2. On occasion, the presence of deoxygenated water in intake embayment areas has resulted in fish kills. Suction at the intake draws an array of microorganisms into the condenser stream (these being too small to be screened out) and most microscopic animals, fish eggs, and larvae are killed by heat and turbulence in passing through the condenser. The number of such entrained organisms is diminished by drawing water from depths of low oxygen content in the manner described above. Recovery rates of phytoplankton from entrainment are rapid at increasing distances from the point of discharge but losses of small fish and other higher forms of animals are irreversible.
3. Water flowing through the copper-nickel or other

alloy tubes of the condenser may pick up small quantities of copper compounds which in sufficient amounts could be toxic to marine life. Titanium has been suggested as a substitute for condenser tubes but as yet this somewhat more exotic metal has had only limited use. From the evidence heard, it does not seem that this is a serious environmental hazard.

4. The flow of estuarine or ocean water through condenser tubes leads to fouling of tube surfaces by marine organisms. If these are not dislodged, heat transfer is greatly inhibited, to the detriment of thermal efficiency. Several methods of removal are used, the three most common being:
  - (a) a mechanical abrading process by which plastic balls dislodge marine growth,
  - (b) the periodic use of chlorine to kill organisms growing on tubes and walls of the cooling water system. In England and California, in contrast to Maryland, continuous low level chlorination is used to prevent fouling. The method uses less chlorine but requires more expensive control devices,
  - (c) the periodic reduction of cooling water flow in order to permit the temperature to rise

sufficiently to kill organisms growing in the system.

If not properly used biocides can be toxic not just to the marine organisms fouling the tubes but to marine life in the estuary. The exercise of very careful controls of concentration and rates of release appear to work reasonably well. The control of biofouling continues to be the subject of research.

5. The discharge of heated water from the condenser outfall creates a "thermal plume" which spreads out into a kind of horizontal and vertical fan the dimensions of which depend upon the winds, tides, sunlight, and temperatures of receiving waters and air. During the cold months this combination of added movement and warmth may well be beneficial to marine life but on still, bright summer days during heat waves, when cooling is least and demand for electricity greatest, the thermal plume has been feared for possible detrimental consequences. These fears, which were prevalent prior to the operation of Calvert Cliffs, do not appear to have been realized. Indeed, more recent strategies for minimizing environmental impact have permitted discharges at higher temperatures in order to diminish the amount of water drawn into the plant, thereby reducing problems of entrainment and entrapment.

### Cooling Towers

In wet cooling towers, condenser cooling water is sprayed over open stacks of slats in a rising current of air. The moving stream of air evaporates some of this sprayed water and discharges it from the top of the tower into the atmosphere. If the draft of air is naturally induced, wet towers are tall (on the order of 400 feet), massive, and clearly visible, an aesthetic impact that is ameliorated, at least to some, by the graceful curves of their appearance. They have the environmental advantage of discharging their moisture laden hot air at heights which enhance dispersion.

In contrast to tall natural draft towers, mechanical draft wet towers have low profiles and are often arranged in groups, usually in a row. They discharge hot, moisture laden air much closer to ground levels. Intermediate designs use combinations of natural and mechanical draft.

All wet towers must provide make-up water to replace that which is evaporated and discharged into the atmosphere. Residues from the evaporated water accumulate in the tower's sump and these must be returned to the natural body of water from which they came. Thus, wet cooling towers have, to a lesser extent, all of the problems described above for once-through systems.

Above wet cooling towers hot, moist air meets cooler and dryer air and the heat exchange causes condensation which creates vapor plumes visible to the eye. The range, density, and duration of these depends upon the winds, temperature, and relative humidity of the receiving atmosphere. Most of the time these vapor plumes are quickly and harmlessly dissipated but there are occasions when light fog can be turned into dense fog and other times when the possibility of icing on highways is increased. Expressed more generally, discharges from wet cooling towers add increments of heat and moisture to the atmosphere around a power plant; most of the time these increments have tolerable effects but at times it can change the weather in the area immediately adjacent to the plant.\*

Wet towers using saline waters also discharge some salt in their vapor plumes and the fall-out of these particles can destroy vegetation downwind from the tower. Such effects can be minimized by careful studies of local meteorology prior to placement of towers and by land acquisition to reserve such areas as may be affected.

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\*Many air conditioners, it should be noted, do exactly the same thing. They cool the air and reduce its moisture content inside and send the hot moist air outside.

Except for aesthetic impact and incremental warming of the atmosphere around power plants, dry cooling towers are environmentally more benign than those which use evaporative cooling but they are very much less efficient. Relative to wet towers, very large amounts of air must be moved and doing so draws off electricity that otherwise would be available to customers.

These environmental concomitants of steam cycles apply to both fossil fuel and nuclear power. There is, however, one quantitative difference: at present, nuclear plants have somewhat lower thermal efficiencies than fossil fuel plants. As a consequence, for any given amount of electricity generated, there is more heat to be removed and returned to the environment of a nuclear power plant than is the case for one which burns fossil fuels.

### Combustion Cycles

Preceding discussion of the environmental effects of power plants has progressed from effects common to all such plants to effects deriving only from thermal plants using steam. We now go still further from the general to the particular, to consideration of the different environmental consequences of fossil fuels versus nuclear fission.

### Fossil Fuels

Since the combustion of coal generally has greater environmental impact than burning oil or gas, and since coal

is likely to provide much more of our electricity in the future, only coal will be considered here.

As a first step, coal must be brought to the power plant in freight cars, barges, or trucks and there stockpiled. Whatever the transportation mode may be, it has environmental impacts which are germane to operation of the coal fired plant even though not directly part of it. The coal pile, like the ash dump mentioned below, and the railroad tracks and freight cars do not improve the environment.

Burning coal creates a conglomeration of combustion products, most of which are gases. Among these, carbon dioxide is dominant but also present are very much smaller amounts of carbon monoxide, water vapor, and the oxides of other ingredients present in the unburned fuel. Most detrimental to the environment are those resulting from the combustion of sulfur, deemed hazardous to health and also to materials, since the oxides of sulfur can convert to sulfuric acid. The oxides of nitrogen also are undesirable because they are conducive to smog but these are more a problem of emissions from automobiles than from power plants.

Carbon dioxide is the dominant emission; it is not poisonous to man and its oxygen is recovered by plants but there is some fear that too much CO<sub>2</sub> can lead to a "green house effect" by reducing long wave backradiation to space to an extent which might profoundly affect the earth's climate.

Carbon monoxide, a consequence of incomplete combustion, is poisonous and its presence must be kept minimal; fortunately, in power plants control of combustion is good and CO discharges are small. Water vapor from the combustion of hydrogen is not a health problem.

In bygone days all of these combustion products were launched into the atmosphere through tall stacks which by their height and by the velocity of discharge gave what then was regarded as sufficient dispersion. Tall stacks are still hallmarks of many fossil fuel power plants but stack gases no longer need escape untreated. The combustion products of sulfur, as explained previously, can be removed in scrubbers which also capture some particulates. These devices do not cleanse stack gases completely of such undesirable emissions. They are, moreover, very expensive, they diminish thermal efficiency and add significantly to the cost of electricity. There are also residues from the scrubbing operation which must be disposed of; environmentally, these are very disagreeable products of combustion.

So also, in a less odious sense, are the particulate residues which may be collected in electrostatic precipitators. These are very fine particles which cannot be dumped like ashes but must be treated first. Ashes accumulate in coal fired plants in sizeable quantities and must be hauled away to suitable dumps. As every citizen old enough to have stoked

an old fashioned coal furnace knows, ash removal and disposition do not improve the environment.

Coal-fired power plants also emit small quantities of radioactive particles - which reminds us that radiation is omnipresent, not just the product of man-made fission.

### Nuclear Fuels

As already said, a major difference between fossil fuel plants and nuclear plants may be the larger environmental burden imposed on site by heat. If the efficiency of a power plant is 40 per cent, generation and transmission to customers of 1000 kilowatts of electricity requires the dispersion of 1500 kilowatts of heat at the power plant. If the efficiency of a power plant is less than this, say, 33 per cent, generation and transmission of 1000 kilowatts of electricity to customers requires the dispersion of 2000 kilowatts of heat at the power plant. The difference between these two numbers, 2000 and 1500, is a measure of the increased local heat burden imposed by lower thermal efficiency.

At present, thermal efficiencies of fossil fuel plants which do not have scrubbers to remove sulfur operate at about the 40 percent level, while pressurized water reactor (nuclear) plants have thermal efficiencies of about 33 per cent. In the future it appears likely that nuclear plant efficiencies will rise while those fired by coal may decline because of the

need for scrubbers. If these trends do come to pass, differences in on-site heat burdens will diminish and perhaps disappear.

Nuclear plants do not generate stack gases, do not emit smoke or particulates, and do not require smokestacks, scrubbers, or electrostatic precipitators. And, except for the very special case of spent fuel, discussed at greater length below, they do not make ashes.

In the early days of electricity generation by fission, radiation was a pervasive fear. Prior to construction, Calvert Cliffs was expected by some to become the source of damaging amounts of tritium, krypton, cesium and other hazardous contaminants conducive to both genetic and carcinogenic damage.

These expectations have not become realities. Compared to natural levels of radiation - that ordinarily are present in the environment - radiation from nuclear power plants is small. Doses of radiation received by members of the public in the vicinity of nuclear power plants are far less than geographical variations in natural radiation within the United States. Now that requirements for strongly limited doses have been formally incorporated in Federal regulations, concern over routine radioactive releases, even among citizens active in the anti-nuclear movement, has diminished appreciably.

SAFETY

The generation and use of high-temperature, high-pressure steam has always been attended by hazards. Long ago, when steam engines were first used in ships, locomotives, and factories, boiler explosions occurred frequently, sometimes with devastating, fatal consequences. This hazard still exists in all power plants using steam but danger from this pent up energy source, despite today's very much higher temperatures and pressures, is no longer considered to be serious. Safe technology, governed by boiler codes, has largely eliminated concerns about boiler explosions. To a much greater extent than has been evident for boilers and other pressure vessels - and other technological hazards as well - safety precautions have been hallmarks of nuclear power. So far, there have been no fatalities from nuclear related causes among operating personnel of commercial nuclear power plants and no injuries or deaths among members of the public.

Despite the excellence of this record, disputes about the safety of nuclear power continue. A major concern relates to speculations about the consequences of what is called a "loss of coolant accident." Such an accident, it is postulated, would occur if the cooling water which circulates through the reactor proper were to be lost suddenly, such as would be caused by a "guillotine" break or rupture in a main pipeline through which the water flows under pressure. If this happened, and if corrective measures failed, there would

be a "melt-down": the temperature from the on-going decay of fission products would rise to a very high level, and this would cause the core materials to melt through the steel of the reactor vessel, and then through the containment structure floor and foundation, allowing escape to the environment of dangerous radioactive contaminants. This scenario, painted in darkest colors by some, is referred to as the "China Syndrome".

Some evaluators do not extend their conjectures through the earth to China but there is agreement that a meltdown could happen and that very serious consequences would follow. At the very least, the power plant would be destroyed, a large area could be made uninhabitable for a considerable time, and a number of fatalities could be caused. The combination of likelihood of occurrence and probable cost of such an accident, however, makes the risk of meltdown less than the risks and costs associated with various other kinds of accidents which are tacitly accepted by society.

To prevent such a catastrophe there are numerous, redundantly numerous instruments and controls to sense and respond automatically to trouble signals of various kinds. There is also a separate supply of cooling water which can be circulated through the reactor in complete replacement of the primary supply should it be lost. This emergency water has its own pumps and a separate supply of power to drive them. Should there be a loss of cooling water of the precipitous kind described, the reactor would automatically

be "scrammed" by insertion of the control rods and the "Emergency Core Cooling System" would reflood the reactor.

Critics have not been satisfied that emergency core cooling systems will work with the quickness and efficacy that may be required, nor have they been satisfied with the numerous computerized simulations that have been used to test safety designs. Demands for an actual test have been made but so far have not been met. Such an experiment would be costly and, whatever the outcome, not necessarily conclusive.

The Panel believes that nuclear power plants are sufficiently safe to warrant their continued existence and their extension for the generation of additional electricity.

#### Accidents

Utilities operating nuclear power plants are required to report the occurrence of every "incident" to the Nuclear Regulatory Commission, in letters signed by designated company officials. The word "incident" is so broadly interpreted and in a climate of such great caution, that hundreds of such letters are prepared and sent even though less than one per cent of the incidents reported bears any relation to safety.

Possibilities for accidents do exist, however, and can be exemplified by the fire which took place at the Brown's Ferry nuclear plant operated by Tennessee Valley Authority.

There a boiling water reactor required maintenance of an air pressure differential between the outside and the

inside of the containment structure. A workman searching for an air leak, found one around a conduit carrying power cables through the wall. He sealed the leak, or attempted to, with a plastic sealing compound and then, to test the seal, lighted a candle to see if its flame would be tilted by continued air movement. The leak had not been sealed and, fanned by the continued draft, the compound caught fire.

At first the workmen attempted to beat out the fire with a flashlight and, that failing, used a carbon dioxide fire extinguisher. By this time, however, the fire had spread to insulation on the cables, among which were those carrying power to the emergency core cooling system. Repeated applications of CO<sub>2</sub> were used; each time the fire would abate, then resume smoldering its way along the cable.

In the meantime the reactor was shut down and the flow of primary water continued. However, had the emergency systems affected by the fire not been rapidly repaired, there could have been a meltdown. As it was, after a time, water could be safely applied to the burning insulation to stop the fire. There was no loss of life or injury but there was considerable damage to the facility. This particular kind of accident can be prevented by pretesting material and selecting those which are not flammable and will continue to carry current under severe conditions.

The Brown's Ferry fire could be attributed to human fallibility and no doubt this will be the cause of accidents yet to come. Human frailty, one may say, is incurable, but may be guarded against by insistence upon the ever-presence of caution.

All persons involved in the nuclear power generating industry recognize the importance of safety measures; yet the exact means and extent of such measures remain open to debate. Some public groups have advocated highly restrictive safety standards which place economic burdens on the industry, while some power companies have been apathetic to public requirements that they pay closer attention to safety. The Panel recognizes that the public has an ongoing and vital interest in requiring the industry to maintain the highest degree of vigilance in safety matters. Government agencies and citizen groups have the right to ask questions of the industry and the industry has the responsibility to respond cooperatively so that both public and private parties can achieve a common goal of continued, unremitting attention to safety matters.

#### SAFEGUARDS

To a very special area of the nuclear cycle the word safeguards has been applied. The topic denoted by the term is a major cause of current concern.

That part of the nuclear fuel cycle which begins with

reactor refueling includes the following sequence:

1. Removal of spent fuel,
2. Cooling and storage at the power plant,
3. Transportation to a reprocessing facility,
4. Chemical reprocessing, to recover recyclable materials,
5. Transportation and remanufacturing into fuel,
6. Transportation of fuel back to the power plant,
7. Reloading into the reactors,
8. Disposition of chemical reprocessing wastes.

Involved in all of these steps is plutonium, a transuranic element\* that is dangerously toxic and dangerously radioactive for a very long time.

Large quantities of plutonium have been made for use in weapons and exist in the form of actual bombs or in wastes from weapons production. Plutonium exists not only in the United States but in every country which has been supplied by us or has succeeded in creating its own A- or H-bombs. Included in this roster are Russia, China, India, France, and the United Kingdom, and very possibly others as well. This

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\*Transuranic elements are those of higher atomic number than uranium, that is, those with atomic numbers greater than 92. All such elements are man-made; most of them are of interest only to atomic scientists (californium, neptunium, einsteinium); some are more toxic than plutonium but plutonium is of transcendent importance, if not of interest, to the world at large.

observation is made simply to point out that the generation of electricity by nuclear fission did not let the atomic genie escape from the bottle. He escaped long ago and man must contrive to live with his menace and profit from his bounty. Strategies of moratoria and retrogression by unilaterally phasing out the nuclear generation of electricity in the United States can neither resolve nor mitigate the problem. International agreements and controls will be necessary.

Despite this ubiquitous dimension to the plutonium problem, the existence and proliferation of nuclear power plants does aggravate the danger. As the number of power plants increases, plutonium, once confined to a limited number of military sites where security has been habitual, will spread into the inventories of power plants and reprocessing facilities, establishments not habituated to armed defense, and into vehicles vulnerable to theft. Unless great care is taken, successful development of the breeder reactor would multiply the amount, dispersion, and accessibility of plutonium throughout the world.

It is difficult to think of any technology which cannot be put to malevolent as well as beneficent purpose. Metals, including plutonium, are of infinite use but they are also the stuff of weapons. Chlorine purifies our water and is a cornerstone in chemistry but it is also a deadly poison. Aircraft fly thousands of peaceful miles every day but they

are also used as artillery, to drop bombs upon fellow humans. As technology has grown more complex and more useful possibilities for misuse have grown too. So it is with plutonium. In the right hands it can give us the energy that we need; in the wrong hands it can confront society with terror.

In the fission of U-235 in pressurized water and boiling water reactors, plutonium is one of the fission products and its presence continues in the spent fuel during cooling and storage at power plant sites. Since it continues to be mixed with other highly radioactive fission products then and during shipment to intended reprocessing plants, theft would be difficult and almost certainly futile during these periods.

At the reprocessing plant this plutonium is recovered and as plutonium metal or plutonium oxide becomes vulnerable to theft, by pilferage from the chemical reprocessing plant or, if recycled to fuel, while in transit through the manufacturing process and back to a reactor.

Given requisite daring, technical sophistication, and the right equipment, it is said that as little as two kilograms (about 4-1/2 pounds) of plutonium can be fashioned into a bomb. There are many who do not believe that this can be accomplished as easily as it has been made to sound but one can speculate that even the allegation of possession, whether true or untrue, would be enough to spread panic

and achieve the purposes of terror and blackmail.

As an alternative to fashioning and threatening to detonate a bomb, terrorists might seek to gain their ends by using, or threatening to use, plutonium as a poison. One speculation is that plutonium could be released as dust into the duct system of a large building, conveyed by that means into working areas, there to be inhaled into the lungs of workers, who remain unaware that from this unperceived poison they will develop cancers ten years hence. This kind of threat, compared to that from a bomb, is heavily discounted; would-be terrorists would do better, it is said, to use other more readily available, more lethal materials for such a mad purpose: chlorine, hydrogen, cyanide, botulism, anthrax.

Having listened and read about these threats, the Panel has come to feel that those which are most extreme are also most exaggerated. As is well known, there are some who are opposed to any form of nuclear power and they make their opposition most effective by predicting Doomsday. However, the Panel also has listened to and read the words of thoughtful and knowledgeable experts on these matters and concludes that safeguarding plutonium is a serious problem which deserves careful attention not only by local authorities, but more particularly by the federal government, and most particularly by concerted international action.

All that locks and bars, seals, instrumentation, detection and signalling devices, materials accounting, guarding, escorting, and swift decisive punishment can do are warranted by the seriousness of the problem. To repeat, plutonium is here and in numerous places elsewhere. Moratorium and roll-back will not solve anything; safeguarding may.

#### STORAGE

From whatever combination of weapons and power plant reactors there may be, some quantity of plutonium and other radioactive substances ultimately must be stored. Pu-239 has a half-life\* of about 25000 years and remains dangerously reactive for many half-lives, about a quarter million years or more. To have and hold plutonium is therefore to have and hold a very hot potato.

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\*The half-life of radioactive material is that period in which its radioactivity decays by half. During the second half-life decay continues to half of the original half, that is, to one quarter of the original intensity. The geometric progression continues in the same halving way during succeeding half-lives, to  $1/8$ ,  $1/16$ ,  $1/32$  etc. The half-lives of many radioactive materials are very short but the radioactivity of plutonium is longlived.

At present there are said to be some 86,000,000 gallons of radioactive wastes from weapons production, an amount as great as may be expected to accumulate from operation of all of present and proposed nuclear power plants to the year 2000. The number sounds big but the volume it defines is not large and, if these liquid wastes are reduced to ceramic concentrates, as has been proposed, storage needs over the next 25 years could be contained in a volume a few feet high in an area the size of a football field.

Either way, as liquid or ceramic, this is not very much to store in volumetric terms but it is, as said, a hot potato requiring deposit in a place of perfect security and geological stability over millenia of time. The best solution proposed so far contemplates storage in containers placed in deep salt formations in the Southwest. These formations are dry and have apparently remained as they now are for a very long time, far longer than 250,000 years.

Among the exotic methods of disposal have been proposals to launch these wastes into outer space, procedures which could consume vast amounts of energy using current technology.

and be potentially dangerous as well.

There are those who object, strongly object, to terrestrial storage of radioactive wastes on moral as well as physical grounds. We shall, it is said, be despoiling the earth for generations yet to come. Indeed, there is an element of truth in this allegation: that tiny part of the earth which is the depository for such materials will be spoiled for use by man for a very long time but, insofar as deep salt formations in the Southwest are concerned, they are of no other value to man and in that sense are already spoiled. The increment of additional spoliation would therefore be small.

The Panel cannot claim to be expert about the storage problem, except to say that it appears to be amenable to adequate solution. Again, the material is here; what to do with it will not be solved by crying halt.

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TECHNOLOGIES

FOR THE

GENERATION OF ELECTRIC POWER



## FOSSIL FUEL TECHNOLOGIES

### Coal

Coal, as everyone knows, is dug from mines which are either subterranean or surface. All coal mining is hazardous to the lives and health of miners and strip mining in particular, causes environmental damage.

Coal is not a product of uniform quality. Most of it is carbon but there are also small but significant percentages of other elements, among which sulfur is regarded as most undesirable. Coal mined in or near Maryland has relatively high sulfur content; Western coal has less sulfur. Excess sulfur may be removed by treatment either before or after combustion; doing so is costly and the residues present disposal problems.

Coal may be burned and electricity generated in power plants contiguous to coal mines but most of it must be transported by rail, ship, or truck to power plant sites located nearer to the areas served. Pipe line transmission in the form of slurry has been proposed but this method requires additional study. Coal may also be liquified or gasified, in which case the combustion technologies are as described below, but these processes also are costly and require much water.

The most widely used method of burning coal is in the form of pulverized particles pumped and blown in a stream into the combustion chamber of a steam generator. The method permits high pressures and temperatures and the use of superheaters\* to increase thermal efficiency, defined as the ratio of the energy produced to the energy content of the fuel. In present-day cycles of this kind thermal efficiencies approximate 40 per cent.

The combustion products of coal are gases, airborne particulates, and ash. Gases and particulates pass out of the combustion chamber and, if not removed, into the stack and escape from the stack into the atmosphere. Most particulates are removed by passing the combustion products through an electric field which ionizes the particles so that they can be captured by "electrostatic precipitation". "Scrubbers" are used to remove most of the oxides of sulfur and also particulates from the stack steam. Both processes

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\*In a boiler the steam which lies above the hot but as yet unevaporated water is called "wet" steam. Wet steam is then passed into a "superheater" which raises its temperature and energy content but not its pressure. This "dry" steam" is then passed thorough the turbine which drives the electric generator.

increase capital and operating costs and present disposal problems.

Ashes, which constitute from 10 to 15 per cent of the coal burned, also must be collected and disposed of, in quantities of hundreds of thousands of tons per year for a typical large power plant.

The steam used to drive the high-and low-pressure stages of the turbine is part of a closed, continuously circulating system. It passes from the superheater through the blade cascades of the turbine, thence to the condenser and through the feed water pump back into the boiler, to be reheated and recirculated.

Steam discharged from the turbine is still hot and vaporous and must be cooled and liquified before it is returned to the boiler. Cooling may be accomplished in "once through" condensers through which cold water is pumped to exchange the heat from the steam to the coolant water through the walls of the many tubes of the device. The water condensed from the spent steam is returned to the boiler and the now warmer coolant to the body of water from whence it came.

In the absence of a sufficient quantity of coolant water to permit once-through condensing, or to minimize aquatic

impacts, cooling towers may be used. In "wet" towers the water from the condenser is sprayed over slats, through which, at the same time, a stream of air is passed (by either forced or natural draft) to evaporate the water and pass the mixture of air, water, and droplets out the top of the tower. Recovered water is collected at the bottom of the tower and once again passed through the condenser. To compensate for losses from evaporation, "make-up" water must, of course, be added.

"Dry" towers operate in the same manner, except that no spray is used. Heat transfer is accomplished by exchange from tubes carrying cooling water through which a moving stream of air is blown. Dry towers do not enjoy the advantage of evaporative cooling and require the movement of much larger volumes of air than wet towers.

Production of the electricity that is the output of the system is accomplished in the generator driven by the steam turbine. As a general rule the most economical plants in a given system will be operated as continuously as possible to meet base-load demands, and less economical units will be added in sequence as demand increases toward whatever the peak-load may be. As peak-loads diminish, the most costly

units are shut down in reverse sequence.

In the coal technology just described the fuel and combustion cycles are different from those for other fuels but the steam, condensing and electric generating cycles are essentially alike for all thermal-electrical systems. As will be shown, there are certain important differences but they are in degree rather than in kind, so the steam, condensing, and electrical components will not be described again.

### Oil

For a variety of fairly obvious reasons, oil is superior to coal as a source of energy for the generation of electricity. Until recently, oil has been relatively easy to find and recover, it has been more amenable to chemical treatment, much easier to transport, less complicated to burn, and less threatening to the environment because of fewer particulates and virtually no ash.

Technologically, oil still enjoys these advantages but they are now mitigated by economic, political, and resource constraints: much higher prices and dependence upon the good will of others for continuity from a limited supply. To counteract this dependence new sources and searches for oil are under development in Alaska and offshore both in the United States and overseas. Recovery from existing wells by various means of enhancing yield and supplies from new

sources will extend a diminishing flow of domestic oil but, as always with mineral products, at higher prices and at a rate insufficient to make us independent of imports. The importance of oil for uses other than electricity generation, petrochemicals and transportation, will inhibit its use in power plants in the future.

There are known to be very large quantities of oil in Colorado and elsewhere in the United States in the form of shale. A measure of false hope has been aroused by reports of this source. Oil can be recovered from shale but the cost of doing so would be very high relative to present prices, the environmental damage would be severe, and the need for water much greater than the available supply. It may be that an economically and environmentally feasible technology for extracting oil from shale will be developed but we do not believe that this can be counted upon.

Prudence therefore argues that we must reconcile ourselves to diminishing the consumption of oil for generating electricity, a policy already embraced by the Federal government by orders to Maryland based utilities to reconvert several power plants from oil to coal.\*

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\*On June 20, 1975 orders were issued by the Federal Energy Administration to Baltimore Gas and Electric Company which, upon their effectiveness, would prohibit the burning of oil in six Baltimore Gas and Electric steam-electric generating units.

## Gas

Given requisite economic parity, gas is an even better fuel than oil but diminution in availability is even more severe for gas than for oil. Reserves are not only diminishing more rapidly for natural gas than for oil but domestic problems have been exacerbated by Federal control of well-head prices for gas sold in interstate commerce. Since uncontrolled prices are very much higher than controlled prices, and since intrastate prices are not controlled, the needs of the gas-rich states have been met, while those of other states, Maryland included, have been cut by significant amounts.

Gas, and oil also, can and probably will continue to be used in the generation of electricity by gas turbines. These prime movers do not use steam but drive electric generators by combustion of the gaseous or liquid fuel in the turbine itself. They enjoy advantages over steam power in quickness and convenience in start-ups and shut-downs and therefore are used most often in power plants designed to meet peak-loads.

The present and prospective scarcity of natural gas and the cost of making gas from coal compels a conclusion that other sources of energy must be used to meet decrements in supply of this important fuel.

### NUCLEAR TECHNOLOGIES

All matter, of whatsoever kind, is composed of atoms and every atom is itself composed of a nucleus about which electrons "orbit". Nuclei in turn are composed of protons, the numbers of which match the number of electrons, and the positive electrical charge of each proton is matched by the negative charge of each electron. There are also particles in the nucleus called neutrons which, as the name implies, are "neutral" since they carry no electrical charge.

A given "nuclide," or species of nucleus, is classified according both to the number of protons - which determines what the element is - and the number of neutrons - which determines which "isotope" of that element is present. One proton and its companion electron are together the structure of every atom of hydrogen. Two protons and their companion pair of electrons are helium; four and four make beryllium; five boron, six carbon, and so on up to 92 protons and 92 electrons, which are uranium.

If a single proton is present, the nucleus, as said, is that of hydrogen. If a neutron is added, the element is still hydrogen but the isotope is given the name deuterium. If a second neutron is added, the hydrogen isotope is called tritium. Uranium, the nucleus of which has 92 protons, has various isotopes with from 135 to 148 neutrons. Rather than give these isotopes unique names, they are simply given alpha-numeric designation such as the now familiar U-238.

The symbol U-238 refers to a nuclide containing 92 protons - making it a uranium nucleus - and 146 neutrons, making a total of 238 particles in the nucleus. Fissionable atoms of the uranium isotope U-235 support the chain reaction in a nuclear power reactor. Elements with more than 92 protons rarely exist in nature but can be made by man. Plutonium is an example of such an element which is discussed in detail elsewhere in this report.

Many nuclides found in nature are "stable"; i.e., they are naturally in a state of minimum potential energy and will not participate in nuclear reactions without an outside source of energy. The majority, however, are unstable, or "radioactive". Such nuclides will spontaneously "decay" in one or more reactions until they become stable. All such reactions are characterized by the emission of one or more subatomic particles carrying large amounts of kinetic energy. This kinetic energy comes from the potential, or "binding energy" of the original nucleus.

This same source of energy is utilized in nuclear power plants, but by a different mechanism. Instead of allowing unstable U-235 atoms to decay slowly, they are made to "fission" by being struck with a neutron. When a U-235 atom fissions, it splits into two smaller atoms (both usually radioactive) and also emits more neutrons and radiation. As these fragments are slowed down by the reactor core materials, their kinetic energy becomes heat.

Reactor cores are carefully designed in terms of geometry, density, and ratio of fissionable to non-fissionable material such that, on the average, only one neutron produced in a fission will strike another U-235 atom and cause another fission. The rest of the neutrons are absorbed in the non-fissionable core materials or in the shield outside the core. Thus, each fission induces another in a "chain reaction," and a steady production of heat can be maintained.

In the case of boiling water reactors and pressurized water reactors, the water serves two functions: it carries away the heat, and it slows down (moderates) the neutrons. Because slowed (thermal) neutrons are more likely to cause U-235 atoms to fission, such reactors can sustain a fission chain reaction with nuclear fuel so low in U-235 content that the chain reaction stops if the water is removed.

One may ask what happens if too many neutrons are absorbed by U-235. Wouldn't the fission rate - and the energy output - increase so fast that the chain reaction would get out of control before mitigating action could possibly be taken? Fortunately, nature has provided a way out of the dilemma. A significant fraction of the neutrons are not emitted immediately following fission; they are delayed for periods of several seconds. Thermal reactors

are designed in such a way that they are never "prompt critical"; i.e., the delayed neutrons are required to sustain the chain reaction. Thus, reactors have a rather substantial safety margin in which manual or automatic safety systems can intervene should something cause the fission rate suddenly to increase. Such "transient" conditions are, in fact, routine occurrences at all reactors. The chain reaction is normally terminated by the insertion of "control rods" made of materials which absorb neutrons without becoming radioactive. Routine power adjustments in the reactor, of course, are made using the same system.

More fundamentally, even if emergency systems do not intervene, natural laws will. Any uncontrolled increase in the neutron flux within the core will inherently trigger changes in the physical state of the core, such as temperature or density, which will restore the chain reaction to equilibrium. Consequently, it is physically impossible for a nuclear reactor to explode like a bomb.

The risk associated with nuclear power plant accidents, discussed elsewhere, comes in quite a different way. There do exist conditions, even when the chain reaction has been stopped, in which the heat contained in the core could not be removed fast enough to prevent the core from melting. Once the core has melted, there is a clearcut potential for the release of major quantities of radioactive materials

into the biosphere.

Actually, the reactor designer must devote considerable attention to insuring that neutrons are not absorbed uselessly in materials other than uranium. Indeed, the difficulty of initiating a chain reaction is such that a complex set of support technologies, known as the "fuel cycle", is required to provide fuel materials in a suitable physical and chemical form to make a chain reaction work.

#### The Uranium Fuel Cycle-First Stage

Uranium is fairly abundant in nature. Most of it, 99.3 per cent, is U-238; the remaining 0.7 per cent is the isotope U-235. It is mined much like coal except that the ore contains large quantities of residues which for the most part are removed at the mine site. The ore is treated to form what is called "yellowcake", an oxide of uranium ( $U_3O_8$ ). For some years uranium mining was not considered to be as hazardous as the subterranean mining of coal but experience led to recognition that the occupation entails exposure to added radiation conducive to a higher incidence of cancer. As a result of precautionary measures this is no longer a serious problem.

The yellowcake is transported to a plant which converts the oxide into uranium hexafluoride ( $UF_6$ ) which, in liquid form, is then transported to a gaseous diffusion plant where the  $UF_6$ , now in the form of gas, is passed through membranes

which differentiate between the lighter U<sub>235</sub> and the heavier U<sub>238</sub> atoms, gradually by successive passes increasing the U<sub>235</sub> concentration. For use in nuclear power plants a level of roughly 3 per cent is sufficient.

The enriched uranium is then taken to a fuel fabricating plant where, in the form of uranium dioxide (UO<sub>2</sub>) it is fashioned into fuel pellets which are placed inside zirconium tubes to make the fuel rods which, when loaded into the reactor, become the energy source for the power plant.

During these stages of the fuel cycle, by exercise of suitable precautions, there is very little danger to workers in the industry nor any to the general public.

At the nuclear power plant for which these fuel rods are intended elaborate advance rehearsals are conducted in simulation of loading and unloading, reloading, starting up and shutting down, et., It is only after this, when all equipment, instruments, water, materials, and manpower are tested, trained, and available, that the fuel rods are loaded into the reactor, along with the control rods which prevent initiation of the chain reaction. When all conditions are "go", the control rods are withdrawn and testing continues over a period of weeks as the reactor is slowly brought up to power.

#### Reactor Cycles

Power plant reactor vessels are large, very massive, and

very strong containers within which the fuel and control rod assemblies are placed. Reactors in the United States use water to moderate neutrons emitted from the fissioning U-235 fuel and also to draw off the heat of fission. This hot water is used to generate the steam which drives the turbine. Most power plant reactors in the United States are either Pressurized Water Reactors (PWRs) or Boiling Water Reactors (BWRs), both of which are classified as Light Water Reactors (LWRs).

#### Pressurized Water Reactors (Fig. 1)

The water that is circulated through the reactor vessel in a PWR to moderate the reaction and carry off the heat of fission is kept in liquid form by high pressure. It flows from the reactor into a second pressure vessel which serves as a heat exchanger and steam generator. There the hot water from the reactor exchanges its heat with this separate, secondary water system, causing it to vaporize into the steam that is passed through the turbine, thence through the condenser, and back into the steam generator. By means of this separate system water which passes through the reactor proper does not pass through the turbine, so that radioactivity is confined to the primary water system.

To exchange heat from primary to secondary water and to maintain liquidity in the primary system and permit

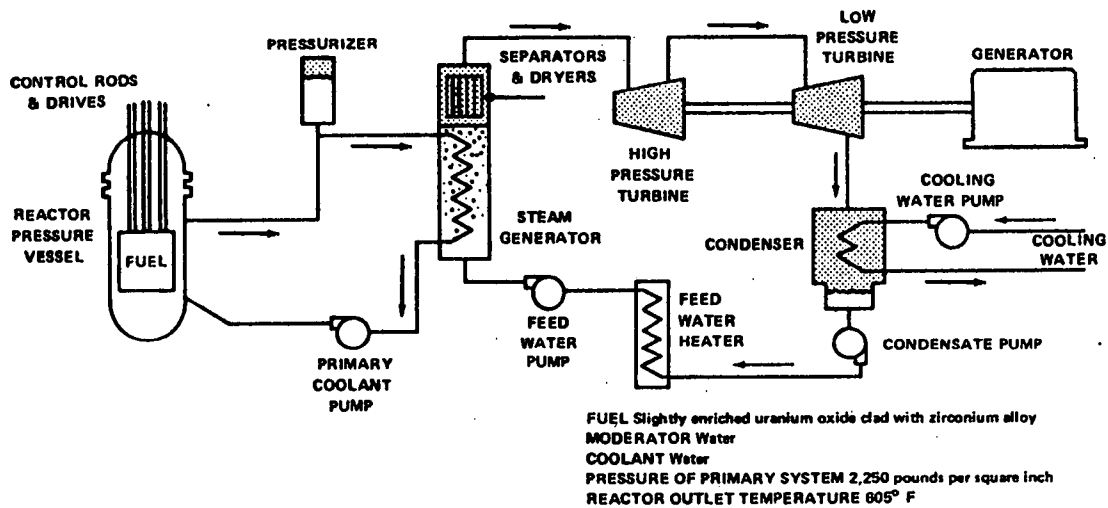


Fig. 1. Schematic diagram of a Pressurized Water Reactor Power Plant. (Courtesy, The Nuclear Power Alternative, Washington, Investor Responsibility Research Center, January 1975, p. 54.)

vaporization in the secondary, there must of course be temperature and pressure differences between the two systems. This requirement, coupled with the need for safe design, has necessitated lower steam temperatures than those used in fossil fuel plants. Since thermal efficiency depends upon the difference between the temperature of steam when it enters the turbine and its temperature in the condenser, this means that PWR efficiencies are lower than those of modern fossil fuel plants. Less of the heat of fission is converted into electricity, so more must be dissipated at the plant site. Previously, efficiencies of fossil fuel plants were given as approximately 40 per cent;\* a comparable figure for present-day LWR plants is 33 per cent. That heat which is wasted must be released at the power plant site. The amounts released in this more concentrated manner are greater from LWRs than from fossil fuel plants of comparable size.

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\*For fossil fuel plants which do not require scrubbers for the removal of sulfur, this figure is approximately correct. When scrubbers are required, thermal efficiencies of fossil fuel plants are reduced by from 3 to 7 percentage points, a reduction which makes their efficiencies - and problems of on-site heat removal - more nearly comparable to LWR plants.

### Boiling Water Reactors (Fig. 2)

Boiling water reactors, known as BWRs, differ from PWRs in that the moderating and cooling water which flows through the reactor is there vaporized into the steam which drives the turbine. The secondary water system described above and shown in Fig. 1 is eliminated. This permits attainment of a slightly higher thermal efficiency and less waste heat but greater precautions are necessary to minimize leakage of radioactive contaminants.

### High Temperature Gas-Cooled Reactors

The moderator in an HTGR is graphite and the cooling fluid is not water but helium gas. The fuel is much more enriched in U-235 than that used in PWRs and BWRs. In HTGRs there is a secondary steam generating system as in the PWR but the steam is generated by heat transfer from the high temperature helium rather than from water. The thermal efficiency of an HTGR, by virtue of higher temperatures and superheat, is much better than for either a PWR or BWR, approaching 40 per cent.

Development of successful HTGRs, however, has been plagued by difficulties. As an example, pertinent to Maryland, orders placed with General Atomic by Delmarva Power and Light for two HTGRs to be constructed at Summit, Delaware, have been cancelled. At present, no HTGRs are in operation in the United States.

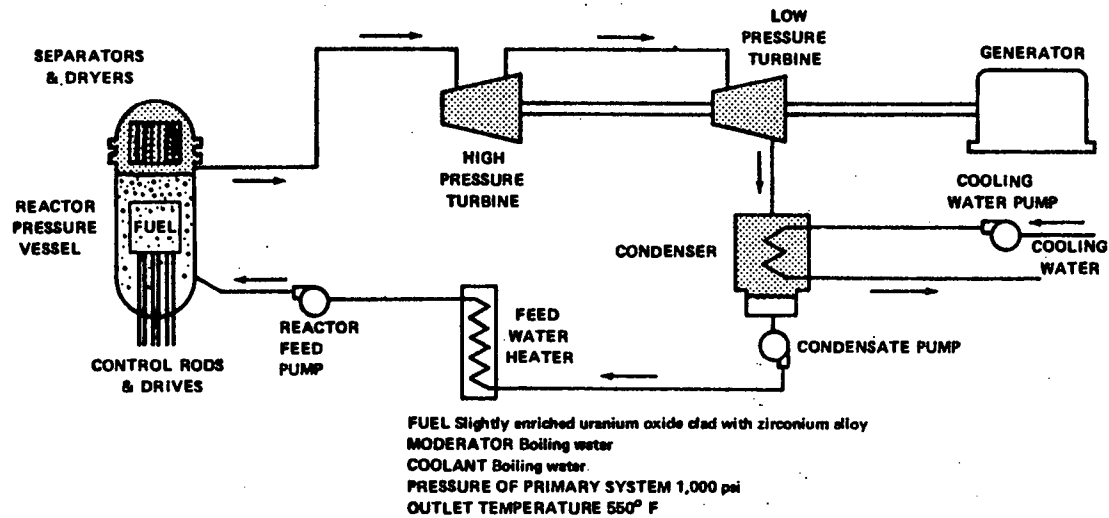


Fig. 2. Schematic diagram of a Boiling Water Reactor Power Plant. (Courtesy, The Nuclear Power Alternative, Washington, Investor Responsibility Research Center, January 1975, p. 54.)

### Liquid Metal Fast Breeder Reactors

The vehicle of heat transfer of an LMFBR is liquid sodium and the fuel is plutonium. In these reactors there is a primary circulating system of liquid sodium, which becomes highly radioactive. It transfers heat to a secondary system also of liquid sodium, which in turn generates steam in a third system carrying water.

The radioactivity of the primary sodium cycle gives cause for concern and so does the proximity of liquid sodium in the secondary system to the water in the steam generator. In this heat exchanger metallic sodium and water are separated only by the thickness of tube walls; any rupture which would bring the two materials together could cause a violent chemical -not nuclear- reaction.

The great advantage foreseen for the LMFBR - and cause for apprehension on the part of some - is that it "breeds" more fuel than it consumes, providing thereby enough nuclear fuel to last for a very long time. That which is "bred" is plutonium. Problems of toxicity, safeguarding, and storing such material were discussed in the preceding chapter.

In the United States construction of a prototype LMFBR has been undertaken by the Energy Research and Development Administration at Clinch River, Tennessee, but it is too soon to predict when or how it will operate. Breeder reactors are already in operation in France, England, and the Soviet Union.

### The CANDU Reactor

North of us Canada is pressing forward with reactors of another kind, reactors in which the moderating fluid is heavy water and the fuel ordinary unenriched uranium, most of which, as already said, is U-238. "Heavy" water consists of atoms of deuterium combined with oxygen, in contrast to "light" water as a combination of hydrogen and oxygen. The difference between the single proton nucleus of a hydrogen atom and an atom of deuterium is the addition of a neutron, the presence of which makes heavy water a substance capable of sustaining and moderating the fission reaction using natural uranium.

Such reactors are in operation by Ontario Hydro and more are planned. Canada is in a favorable position with respect to resources for the nuclear generation of electricity and it would not be surprising to see them exporting power to the United States.

### The Uranium Fuel Cycle-Second Stage

As the fission cycle delivers its energy in the manner described above, part of the initial charge of fuel rods becomes spent, so that at scheduled intervals the reactor must be shut down and the spent fuel rods withdrawn and replaced. When reloading has been accomplished operation of the reactor is resumed.

The rods removed in refueling have been characterized as "spent" but in fact they are still radioactive and generate heat due to the decay of fission products. The rods still contain fuel materials which can be recovered for reuse. Present practice is to store and cool them for an initial period in a segregated area at the plant site.

Ultimately, the intention has been to ship spent fuel rods to reprocessing plants at which reusable components can be extracted for inclusion in new fuel rods. The reprocessing plants which have been operated in the past are now shut down and it is not known when resumption of reprocessing will be permitted by the Nuclear Regulatory Commission.

The principal reason for this precautionary moratorium appears to be plutonium. This dangerous substance can be removed from spent fuel and used in new fuel rods, at a considerable saving, but this would involve increasing transportation of plutonium, regarded by some as a hazard to which society should not be exposed.

Problems of safety and safeguarding were discussed previously; suffice it to say here that spent fuel from Calvert Cliffs is to be stored there temporarily in a facility capable of holding a five-year accumulation. What will be done then or before then will be dependent upon possible changes in the law which now bans reprocessing in Maryland altogether and forbids storage of spent fuel for more than two years.

TRANSMISSION TECHNOLOGY

High voltage transmission lines are much more evident now than they once were because there are more of them and because we move about more and have more visual encounters with them. Some object to their march across the country, others find their catenaries graceful and new towers pleasing but these aesthetic considerations are not the subject here.

Technologically, electric power transmission progresses toward higher and higher voltages for the very simple reason that line losses are proportional to the square of the current times line resistance (known as the " $I^2R$  loss"). Since the power transmitted is the product of current times voltage, transmission of any given amount of power may be best effected at highest voltage and least current. Recently, Maryland utilities have been using a transmission voltage of 500,000. Nationally, there are some lines at 765,000 volts, and levels above 1,000,000 volts have been projected for the foreseeable future. While there are environmental impacts related to this trend, its technological significance also is important: higher voltages permit economical transmission over longer distances. This relates not only to previous mention of the possible export of electricity by Canada but, closer to home, the possibility of "nuclear parks" where a number of reactors may be centered in locations more distant from centers of population. Concentrations of this kind

would lessen the hazards of moving dangerous materials, improve security, and perhaps permit reprocessing on site, but available water and "heat island" and other environmental effects must be examined.

A federal study of the nuclear park concept has been mandated by the legislation which created ERDA and NRC: this study is expected to be released in 1976.

#### HYDRO

Development of energy by passing water through water wheels and turbines has a long history of usefulness. In the early days of electricity hydro power supplied a significant fraction of the electric energy produced. Over the years rivers have continued to be dammed for the development of hydroelectric power, so that by now most of the economic sites have been exploited. The Edison Electric Institute forecasts a five year growth in annual hydroelectric energy generation of from 238 billion to 244 billion kilowatt-hours while total generation is expected to grow from 1,800 billion to 2,700 billion kilowatt-hours. The 4 billion growth in hydroelectric energy is less than 0.5 per cent of the 900 billion growth predicted for total energy production.

Hydroelectric energy has many advantages: its production is clean, it uses a renewable resource (river flow), it can be stored till needed, and it can be extracted on a

moments notice to meet rapid changes in demand. The Potomac River is the only stream in Maryland that has a significant undeveloped potential for hydroelectric power. In view of other uses of the River and its valley it is doubtful that this potential will be available in the foreseeable future.

#### SOLAR

Sunlight can be used to generate electricity either by concentrating heat to drive some form of heat engine coupled to an electric generator, or by photovoltaic means, exemplified by the solar batteries which generate the power used by space vehicles. Neither is now an economically attractive technology for generating electricity in significant amounts.

Even in so favorable a spot as the Arizona desert, the accumulation of heat energy from the sun's rays would produce electricity that would not be competitive with generation from fossil fuel or nuclear fission. Moreover, the difference in cost would be substantial and, in much cloudier Maryland, out of sight. For us, the generation of electric power by this means holds little promise.

Electric generation by photovoltaic means holds much more promise than from sun-powered heat engines but this technology is not economically feasible at present and will not be until a way can be found to mass produce silicon wafers of sufficient efficiency. Even when this problem

has been solved large areas will be required for exposure to the sun and large numbers of batteries required to collect, store, and transmit the electricity generated. Photovoltaic electricity may one day become a significant incremental source of electricity in suitable areas but for the present it should not capture the hopes of policy makers in Maryland.

Solar energy for space and water heating is another matter; this is a technology which does hold immediate promise in Maryland. At present, houses can be sufficiently and uniformly warmed by collecting and storing heat from the sun if used in conjunction with heat pumps\* or other auxillary sources. As the footnote suggests, the heat pump - solar technology can be applied to air conditioning as well as to space and water heating.

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\*Heat pumps are used to compress gas; in doing so they make the gas hot and this heat may then be used in company with solar heat to warm a home or to heat water. The compressors of electric refrigerators and air conditioners also are heat pumps but with opposite purpose: they compress the refrigerant gas and make it hot; the heat of compression is then radiated outside the refrigerator or house and the cooled gas then allowed to expand, at which time its temperature drops to provide the cooling medium for refrigeration or air conditioning.

### WIND

Windmills as sources of energy have been proposed for both land and sea and, to be sure, there are possibilities for such devices in suitable localities but their contributions are likely to lie in the future. Like sunlight, the energy supply costs nothing but the source is intermittent and diffuse and the capital cost of capturing the energy and collecting it in significant amounts is considerable, to say nothing of the environmental impact of multiple windmills whether they be on land or anchored in the ocean trade winds.

The Panel does not derogate the increments of energy to be derived from any source - every little bit will help as the saying goes - but we shall not get sufficient relief from the wind to avoid expanding the generation of power by use of coal and nuclear energy.

### WAVES AND TIDES, GEOTHERMAL, OCEAN THERMAL, FARMING

Other unconventional technologies which may yield some increments of energy are those listed in the sub-head above. The ebb and flow of waves and tides expend very large amounts of energy but possible use is confounded by a combination of diffusion over large areas and distances, the vagaries of time and directional reverses, and of collecting and transmitting the energy. Interest has been revived in the long abandoned Passamoquoddy tidal project but even if success

is achieved there the consequences are not likely to be important to Maryland where tidal variations are much smaller.

Geothermal energy is realized in some parts of the United States and there is talk of deep drilling to use the temperature differences between the surface and the earth's core to drive heat engines. However, this resource is more likely to be developed in the Western and Gulf States than in Maryland.

Temperature differences between ocean water at the surface and at the depths is also proposed for use in an analogous manner. Again, development may be confined to deep tropical waters where such differences are greatest. Even there, however, the temperature differentials are small compared to combustion and nuclear devices.

Farming and other forms of bioconversion are mentioned here as other possible sources of energy under study. Harvestable crops and waste products\* could be used for conversion to power or, more likely, to chemical products such as methane, to add to our energy resources.

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\*The pyrolysis plant, currently under "shakedown" operation in Baltimore, provides an example of the generation of useful heat from waste products.

These unconventional energy sources are not always proposed for the direct generation of electricity but for conversions into useful chemicals, such as the methane just suggested. Hydrogen and ammonia have been among other conversion products proposed.

Policy makers should not be beguiled by the fact that these unconventional energy sources from the sun, wind, and seas are "free". The sources are free but conversion to electricity will be very costly, much more so than other available choices.

#### FUSION

One alternative energy source of great potential is controlled thermonuclear fusion. This involves harnessing the nuclear energy released when light nuclei combine. These reactions occur in stellar interiors, and provide the heat of the sun and other stars. Man has utilized the same reactions in constructing the hydrogen bomb. Extensive research currently is underway to diffuse the energy of thermonuclear reaction so that it can be controlled and used constructively.

The potential benefits of fusion are impressive. Its radioactivity release may be much less than for nuclear fission, since only tritium among the nuclear products of the thermonuclear reactions is radioactive. The basic fuels are almost limitless; it is estimated that there is in our

oceans sufficient deuterium to fuel mankind's fusion reactors for billions of years. In addition, the problems of nuclear safety and safeguards would be quite manageable, since a fusion plant could not explode or be converted to the manufacture of thermonuclear weapons.

However, fusion research programs have not yet solved the considerable scientific and engineering problems in controlling thermonuclear reactions. Even if scientific feasibility is demonstrated within the next decade, it could take an additional 10-20 years of development and engineering to provide an economically viable option for the generation of electricity. As a result, energy derived from controlled fusion must be considered a distant but very inviting possibility.



## APPENDIX A

### MEMBERS OF THE PANEL

The following individuals were appointed by the Power Plant Siting Program to serve as the Panel:

Robert H. Roy, B. E. (Chairman), Research Associate and Principal Investigator, Center for Environmental and Estuarine Studies, University of Maryland; Professor Emeritus of Industrial Engineering and Dean Emeritus of Engineering Science, The Johns Hopkins University; Member, Governor's Science Advisory Council.

John C. Geyer, Dr. Eng. (Vice-Chairman), Principal Research Scientist, The Johns Hopkins University; Member, Advisory Commission on Atomic Energy; Member, Power Plant Siting Advisory Committee.

Howard Laster, Ph.D. (Vice-Chairman), Professor, Department of Physics and Astronomy, University of Maryland College Park; Former Chairman, Governor's Science Advisory Council.

Doris R. Entwisle, Ph.D., Professor of Social Relations and Engineering Science, The Johns Hopkins University.

Anthony C. Fisher, Ph.D., Associate Professor of Economics, Bureau of Business and Economic Research, University of Maryland College Park.

Albert Gomezplata, Ph.D., Professor and Chairman, Department of Chemical Engineering, University of Maryland College Park.

Donald R. Heinle, Ph.D., Research Associate Professor, Center for Environmental and Estuarine Studies, University of Maryland.

Joseph H. McLain, Ph.D., President, Washington College.

Member Governor's Science Advisory Council.

Donald E. Milsten, Ph.D., Assistant Professor of Political Science, University of Maryland Baltimore County.

Frank J. Munno, Ph.D., Professor and Director, Nuclear Engineering Program, University of Maryland College Park.

Garrett Power, LL.M., Professor of Law, University of Maryland at Baltimore.

Henry N. Wagner, Jr., M.D., Professor of Medicine, Radiology, and Environmental Health, School of Hygiene and Public Health, and School of Medicine, The Johns Hopkins University. Director of Nuclear Medicine, The Johns Hopkins Hospital.

In addition, the Power Plant Siting Program appointed Mr. Darryl R. Holliday, Associate Physicist, The Johns Hopkins University Applied Physics Laboratory, as Technical Staff Advisor to the Panel.

## APPENDIX B

### MEETINGS AND OTHER ACTIVITIES OF THE PANEL

As part of its investigations, the Panel held a series of public meetings which were addressed by experts on issues relating to nuclear power. The programs of these meetings are listed below:

June 30 - July 1 - University of Maryland Baltimore County

General Topic: Review of the 1969 Report of the Governor's  
Task Force on Nuclear Power

Demand Forecasts:

John W. Wilson, Economic Consultant, Department of  
State Planning, State of Maryland,  
William E. Miller, Manager, Economic Research Department,  
Baltimore Gas and Electric Company,  
Frank S. Walters, Vice-President, Rates and Regulatory  
Practice Group, Potomac Electric Power Company,  
J. Edwin Hobbs, Vice-President and Manager of Operations,  
Delmarva Power and Light Company,  
John J. Boland, Visiting Associate Professor of  
Geography and Environmental Engineering, The Johns  
Hopkins University.

Environmental Impacts:

Steven Long, Administrator for Nuclear Evaluation,  
Maryland Power Plant Siting Program,

William A. Richkus, Research Scientist, Martin-  
Marietta Laboratories,

Edward P. Radford, Professor of Environmental Medicine,  
School of Hygiene and Public Health, The Johns  
Hopkins University,

Hugh Thompson, Environmental Projects Manager, Nuclear  
Regulatory Commission,

David L. Thomas, Ichthyological Associates, Inc.

Regulation:

Lawrence C. Kohlenstein, Assistant Supervisor, Power  
Plant Siting Group, The Johns Hopkins University  
Applied Physics Laboratory,

Edward Lawson, Special Assistant Attorney General,  
Maryland Power Plant Siting Program,

Sheldon A. Schwartz, Special Assistant for State  
Relations, Nuclear Regulatory Commission.

August 14, 1975 - The Johns Hopkins University Applied  
Physics Laboratory

General Topic: Site Specific Considerations

Staff of the Power Plant Siting Group, The Johns Hopkins  
University Applied Physics Laboratory, Lawrence C.  
Kohlenstein Acting as Principal Spokesman for site  
evaluation of the nuclear plant proposed for Douglas  
Point.

John J. Scoville, Manager of Environmental Affairs,  
Potomac Electric Power Company,

Tibor Polgar, Project Director, Martin-Marietta  
Laboratories,

Loren D. Jensen, President, Ecological Analysts, Inc.

September 17-18, 1975 - The Johns Hopkins University

General Topic: Alternatives for the Generation of  
Electricity

Frederick T. Sparrow, Division Director, Division of  
Advanced Productivity, Research and Technology,  
National Science Foundation; Professor-Elect of  
Industrial Engineering and Economics, University of  
Houston,

James L. Everett, President, Philadelphia Electric  
Company,

Milton Edlund, Director, University Center for Energy  
Research, Virginia Polytechnic Institute and State  
University,

C. Edward Utermohle, Jr., Chief Executive Officer,  
Baltimore Gas and Electric Company,

Allen L. Hammond, Research Editor, Science, American  
Association for the Advancement of Science.

October 13-14, 1975 - University of Maryland College Park

General Topic: Nuclear Safety, Safeguards, and Wastes

Charles D. Flagle, Professor of Operations Research,  
The Johns Hopkins University,  
Romano Salvatori, Manager, U.S. Projects, Pressurized  
Water Reactor Systems Division, Westinghouse Electric  
Corporation,

Robert Davies, Manager, Quality Assurance Department,  
Baltimore Gas and Electric Company,

Theodore Taylor, Consultant, International Research  
and Technology Corporation,

Thomas Cochran, Natural Resources Defence Council,

Bernard L. Cohen, Professor of Physics, University of  
Pittsburgh,

W. Bennett Lewis, Distinguished Professor of Science,  
Queen's University, Kingston, Ontario,

David P. Ross, Director, Energy-Environmental Programs,  
Southern Interstate Nuclear Board.

In addition, members of the Panel visited the Calvert  
Cliff Nuclear Power Plant on September 30, 1975.

Individual members of the Panel participated in the  
following meetings and programs:

May 6-9, 1975 - Atomic Industrial Forum, Chicago.

May 15, 1975, - "Is Nuclear Power Safe?" American  
Enterprise Institute, Washington.

July 7-25, 1975 - Massachusetts Institute of Technology  
Summer Course on "Nuclear Reactor  
Safety," Norman C. Rasmussen, Instructor.

July 23, 1975 - "Concerned Citizens of Kent County  
Against Atomic Power," Kennedyville,  
Maryland.

September 21-25, 1975 - "Nuclear Power and the Energy  
Crisis," Oak Ridge Associated  
Universities, Oak Ridge,  
Tennessee.

The Panel held a number of meetings for discussion and  
review during the course of the study.

